

DISC DRIVE APPARATUS HAVING DRIVE
ELECTRONICS TOP MOUNTED ON FLEXIBLE
PRINTED CIRCUIT BOARD

by

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**DISC DRIVE APPARATUS HAVING DRIVE ELECTRONICS TOP
MOUNTED ON FLEXIBLE PRINTED CIRCUIT BOARD**

Related Applications

5 This application claims priority of United States provisional application
Serial Number 60/404,682, filed August 20, 2002.

Field of the Invention

This application relates generally to data storage devices and more
particularly to the placement of electronic control circuit components in a data
10 storage device.

Background of the Invention

Disc drives are data storage devices that store digital data in optical, opto-magnetic, and/or magnetic form on a rotating storage medium on a disc. The typical disc drive includes a base plate on which various structural components are mounted. The various structural components include, for example, a disc, an actuator assembly, and a spindle motor rotating the disc. Modern magnetic disc drives comprise one or more rigid discs that are coated with a magnetic medium and mounted on a hub of the spindle motor for rotation at a constant high speed. Information is stored on the discs in a plurality of concentric circular tracks
15 typically via an array of transducers mounted to a rotary actuator for movement of the heads relative to the discs. The discs drive motor assembly, collectively known as a head/disc assembly (HDA), a devise having all control electronic circuits integrated above the base plate, and the actuator are typically enclosed on the base plate by a cover forming a sealed environment to prevent contamination within the
20 system that could result in disc failure.

The typical disc drive also includes a printed circuit board assembly that provides the majority of the electronic circuits necessary for control of operation of the disc drive, including controlling positioning of the actuator and transducers. This printed circuit board assembly is mounted outside the sealed head disc
25 assembly traditionally, beneath the disc drive plate on an underside surface of the base. Input and output signals are fed to and from the disc drive via the printed

circuit board circuitry and the HDA. These signals are typically supplied to the HDA via a pass-through connector that extends through and seals an opening into the enclosed head disc assembly and then through a flexible printed circuit cable to the actuator assembly. The printed circuit cable has one end physically terminating 5 on the actuator assembly and the other end connected to the pass-through connector. These terminations inherently exhibit losses.

One problem that has arisen with this design is that it necessitates several connections between the components on the printed circuit board and the flex-circuit cable, which increases the losses in the electrical circuitry system.
10 Accordingly there is a need for a disc drive system that reduces or eliminates these problems. The present invention provides a solution to this and other problems, and offers other advantages over the prior art.

In addition, the printed circuit board, the pass-through connector and flex-circuit cable are traditionally attached to the base plate and then physically 15 electrically connected to each other in separate steps. Because the manufacturing process currently requires these separate steps, it is also desirable to provide a system that eliminates some of these steps.

Summary of the Invention

20 Against this backdrop embodiments of the present invention have been developed. One embodiment of the invention features a disc drive having all of its actuator servo-controls and signal processing electronics circuitry incorporated onto a flexible printed circuit assembly positioned on a top surface of the base plate adjacent the external power and interface connector of the disc and alongside the
25 head disc assembly (HDA), which includes the actuator assembly and the discs mounted on the spindle motor enclosed between the base plate and cover. In this embodiment, the top cover together with the base plate encloses only the HDA. The cover avoids the power, actuator servo-controls and signal processing electronics components mounted on the flexible printed circuit board adjacent the
30 HDA so that these components may be cooled by ambient air circulation.

In another aspect of the invention, the flexible printed circuit board is attached to a stiffener plate against a bottom surface of the flex printed circuit

board. This stiffener plate functions in a multiplexing fashion as an electrical ground plane and a power plane for the components mounted on the flex printed circuit assembly. The printed circuit assembly and power and ground plane stiffeners are electrically connected to the components by a network of metal stakes. The flexible printed circuit board and stiffener plate assembly is inserted into and connected to the external power and interface connector that is, in turn, fastened to the base plate of the disc drive.

The flexible circuit board assembly of the invention includes a pigtail lead trace that extends beneath the discs in the HDA to provide power to the spindle motor. The flexible circuit board also includes a lead trace that connects to the actuator assembly within the HDA.

In an alternative embodiment the flexible circuit board assembly includes an actuator lead pad to which a separate lead trace, fastened to the actuator assembly during HDA assembly, is connected.

These and various other features as well as advantages which characterize the present invention will be apparent from a reading of the following detailed description and a review of the associated drawings.

Brief Description of the Drawings

FIG. 1 is a plan view of a disc drive incorporating one embodiment of the present invention showing the primary internal components of the disc drive beneath the cover in dashed lines.

FIG. 2 is a separate exploded perspective view of a flexible printed circuit assembly of the embodiment shown in FIG. 1.

FIG. 3 is a separate plan view of the flexible printed circuit assembly shown in Figure 2.

FIG. 4 is a perspective view of the disc drive in Fig. 1 with the cover spaced from the head disc assembly.

FIG. 5 is a plan view of a disc drive in accordance with an alternative embodiment of the present invention as in FIG. 1 with the top cover in place.

FIG. 6 is a separate plan view of the alternative flexible printed circuit assembly and connector in the embodiment shown in Figure 5.

FIG. 7 is a perspective view of the disc drive in accordance with the alternative embodiment of the present invention shown in FIG. 5 with the top cover spaced from the head disc assembly.

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Detailed Description

A disc drive **100** constructed in accordance with an embodiment of the present invention is shown in FIG. 1. Throughout this specification like numerals will be used to identify like elements in the various embodiments shown and described for consistency and ease of identification. The disc drive **100** includes a base plate **102** to which various components of the disc drive **100** are mounted. This base plate is essentially a generally rectangular plate that has a peripheral wall to which a top cover **104** is attached. The top cover **104** cooperates with the base plate **102** to form an internal, closed head disc assembly (HDA) environment for several of the various components of the disc drive. These components are shown in dashed lines in FIG. 1. The components include a spindle motor **106** that rotates one or more data storage discs **108** at a constant high speed. Each of these data storage discs supports on its surface a storage media such as optical media or a layer of magnet media. Information is written to and read from tracks on the discs **108** through the use of an actuator assembly **110**, which rotates during a seek operation about a bearing shaft assembly **112** positioned adjacent the discs **108**. The actuator assembly **110** includes a plurality of actuator arms **114** which extend towards the discs **108**, with one or more flexures **116** extending from each of the actuator arms **114**. Mounted at the distal end of each of the flexures **116** is a head **118** that includes a fluid bearing slider enabling the head **118** to fly in close proximity above the corresponding surface of the associated disc **108**.

During a seek operation, the track position of the heads **118** is controlled through the use of a voice coil motor (VCM) **124**, which typically includes a coil **126** attached to the actuator assembly **110**, as well as one or more permanent magnets (not shown) which establish a magnetic field in which the coil **126** is immersed. The controlled application of current to the coil **126** causes magnetic interaction between the permanent magnets and the coil **126** so that the coil **126** moves in accordance with the well known Lorentz relationship. As the coil **126**

moves, the actuator assembly 110 pivots about the bearing shaft assembly 112, and the heads 118 are caused to move across the surfaces of the discs 108.

A flex printed circuit board assembly 130, in accordance with an embodiment of the invention, provides the requisite electrical connection paths to and from the actuator assembly 110 while allowing pivotal movement of the actuator assembly 110 during operation, supports power and control electronics components for the spindle motor 106 and control of the actuator assembly 110, lead traces to a preamplifier mounted on the actuator assembly 110 and lead traces connected to the motor 106. The head wires (not shown) are routed from the preamplifier 165 along the actuator arms 114 and the flexures 116 to the heads 118.

The flex printed circuit board assembly 130 in the embodiment shown in FIG. 1 is separately shown in FIGS. 2 and 3 and a perspective view of the installation of the flex assembly 130 is shown in FIG. 4. The flex assembly 130 preferably includes circuitry for controlling the write currents applied to the heads 118 during a write operation and a preamplifier 165 for amplifying read signals generated by the heads 118 during a read operation. As is shown in FIG. 2, the flex assembly 130 has a flexible printed circuit 131 and a stiffener plate 140 fastened to the flexible printed circuit 131. The stiffener plate 140 and circuit 131 are in turn inserted into a slot in the rear of the connector 150 to electrically connect the traces on the circuit 131 to the connector pins of the connector 150. The connection between these pins and the traces (not shown) may be compression fit, soldered in place in a conventional manner, or otherwise electrically and physically connected to complete the flex assembly 130.

The flex assembly 130 preferably includes a multi-chip packaged (MCP) component 132 (also called a multi-chip module), passive components 133 such as discrete resistors, capacitors and diodes, and a power combo chip 134 soldered, or otherwise physically fastened, directly onto the flexible circuit 131 of the flex assembly 130. MCP's are modules that have multiple integrated circuits packaged on an insulating substrate. The integrated circuits are interconnected on the MCP component 132 and the MCP component 132 has external connections. The flex assembly 130 in its entirety takes the place of a rigid printed circuit board that is traditionally attached beneath the base plate of the drive. All of the typical

modules found in a disc drive control system, such as an interface module, microprocessor, memory, read/write channel, and disc controller are incorporated into these components **132** and **134**.

The power combo chip **134** preferably includes the output circuitry
5 necessary to control and drive the VCM **124** and the spindle motor **106**. The external connections of the MCP component **132** and the power combo chip **134** are preferably soldered directly onto the flexible circuit **131** of the flex assembly
130.

The standard external interface connector **150** is fastened to one end of the
10 base plate **102** for connection of the drive **100** to external components (not shown). The stiffener plate **140** is preferably made of aluminum, as is typically the base plate **102**. The flexible circuit **131** of the flex assembly **130** is preferably bonded to the aluminum stiffener **140**, for example, using an adhesive. In addition to providing stiffness for connecting and disconnecting the connector **150** from the
15 assembly, the stiffener **140** provides a ground plane **141** for the electronics on the flex assembly **130**. In addition, the stiffener **140** incorporates an insulated power plane **142** connecting power to components **132** and chips **134**. Power plane **142** preferably rests on a layer of insulating material, such as Mylar, to insulate the power plane **142** from the ground plane **141** of the aluminum stiffener **140**. The
20 power plane **142** may alternatively simply be routed out of the stiffener **140** to separate it from the ground plane **141**. Power plane **142** and ground plane **141** would then simply be insulated from each other by a horizontal gap between them formed by the routing operation. The ground plane **141** and power plane **142** would then be adhesively bonded to the flexible circuit **131** and the components
25 **132**, **133** and **134** staked to the power plane and ground plane **142** and **140** via pins on the components and pads on the flexible printed circuit **131**.

Figure 3 is a plan view of the flex printed circuit assembly **130** connected to the connector **150**. The flexible circuit **131** has a generally rectangular portion and an elongated connector portion along one edge inserted within the connector **150**,
30 coextensive with the stiffener plate **140**. The flexible circuit **131** has pigtail leads **162** and **164** extending from edges of the rectangular portion spaced from the connector portion. These pigtail leads **162** extend beneath the cover **104** of the disc

drive 100 as shown in FIG. 1. Pigtail lead 162 preferably carries, at its free end, a preamplifier 165. This preamplifier 165 is mounted on the side of the actuator assembly 110, as close as possible to the heads 118 on the actuator assembly 110 and is used to amplify the small read signals from the heads 118. An alternate 5 location for the preamplifier 165, not shown, may be on the flex circuit adjacent the components 132 and 134, although, with the small signal strengths of signals from magnetoresistive read elements on the heads 118, a remote mounting of the preamplifier 165 is preferred. Pigtail lead 162 forms a curved flexible service loop type connection between the electronics on the flexible circuit 131 and the actuator 10 assembly 110 so as to minimize any torque on the actuator arms in a conventional manner. Pigtail lead 164 extends from the edge of the rectangular portion of the flexible circuit 131 and lies essentially flat and extends straight under the discs 108 to the spindle motor 106. Pads on the lead 162 contact a connector on the bottom of the motor 106 to provide the requisite electrical connections to the motor 106.

15 The flex assembly 130 is preferably fastened to the base plate 102. The attachment to the base plate 102 can be achieved by a variety of methods. For example, the flex assembly 130 can be screwed or staked onto the base plate 102 or it could be attached using a pressure-sensitive adhesive. The flex assembly 130 is preferably installed on the base plate 102 prior to placement of the HDA 20 components on the base plate 102. Assembly of the flex assembly 130 and connector 150 to the base plate 102 does not need to take place in a controlled clean room. Once the flex assembly 130 is attached to the base plate 102, the unit 25 can then be placed in a clean environment, and the actuator assembly 110, discs 108 and spindle motor 106 installed. Then the lead 162 of the flex assembly 130 can be attached to the actuator assembly 110, and the head wires connected to the preamplifier 165 respectively.

Alternatively, the leads 162, 164 of the flex assembly 130 could be soldered to the actuator assembly 110 and spindle motor 106 prior to attachment of the flex assembly 130 to the base plate 102. The manner in which the leads 162, 164 connect to the actuator assembly 110 and spindle motor 106 is generally known 30 and further description is not necessary. Pigtail lead 162 can be formed into a

service loop and alternatively attached to an aluminum L-bracket either separately fastened to the base plate 102 or integrated into the stiffener 140.

Once the leads 162, 164 are connected to the actuator assembly 110 and spindle motor 106, the top cover 104 is installed onto the base plate 102. This attachment is generally achieved by screwing the top cover 104 onto the base plate 102. A flexible seal is placed around the perimeter of the top cover 104 between the cover 104 and the base plate 102 in order to ensure that the environment between the top cover 104 and the base plate 102 remains clean and uncontaminated. This seal is preferably located under the peripheral edge of the cover 104 so that the cover 104 is pressed uniformly against the base 102, against and over the leads 162, 164 to maintain the HDA free of contaminants when the cover 104 is securely fastened to the base plate 102 via screws or other fasteners.

As shown in Figures 1 and 4, the top cover 104 is shaped so that it covers all the major moving components of the disc drive, such as the actuator assembly, disc, and spindle motor, and yet clears the rectangular portion of the flex assembly 130 supporting the electronic control and power components 132 and 132. Preferably, the top cover 104 only covers the leads 162 and 164 of the flex assembly 130. Although not shown in the exemplary embodiments illustrated, the cover 104 may extend to and cover portions of the connector 150.

The top cover 104 is preferably shaped in this manner for several reasons. Because the flex assembly 130 is located outside the top cover 104, the flex assembly 130 does not have to be manufactured and/or assembled in a clean room environment. Therefore, manufacturing costs can be decreased. Also, because the MCP 132 and power combo chip 134 are outside of the covered HDA, those electrical components remain available for further final testing after the top cover 104 is assembled onto the base plate 102. In addition, these components receive convection cooling from surrounding airflow.

By providing MCP component 132 and power combo chip 134 on top of the flex assembly 130, physical electrical connections are minimized and traditional connectors can be eliminated. For example, the disc drive 100 no longer requires a pass-through connector to conduct power and signals between the printed circuit board on the underside of the disc drive to elements of the disc drive

that are mounted on the topside of the base plate. The overall footprint and form factor of the drive can be reduced. The bottom of the disc drive **100** may be flat, and eliminating any need for spacing from adjacent structures and may facilitate denser packaging of multiple disc drives together.

5 An alternative embodiment of a flex assembly **230** is shown in FIGS. **5**, **6**, and **7**. In this embodiment, the principal difference from assembly **130** is in the arrangement of the pigtail lead **266** that is electrically connected to the actuator assembly **110**. In this alternative embodiment **230**, the description set forth above regarding the structure of the stiffener **140**, the ground plane **141** and power plane **142**, the staking interconnection of the planes with the flexible circuit components **132**, **133** and **134**, and connector **150** is the same and therefore will not be repeated here. The pigtail lead **264** which leads to the spindle motor **106** also remains the same as in the first embodiment **130**. The pigtail lead **266**, for the actuator assembly **110**, in this alternative, is different.

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15 In this alternative embodiment, a separate pigtail lead **268**, with a preamplifier **265** attached, is preferably separately assembled to the actuator assembly **110** prior to assembly of the head disc assembly onto the base plate **102**. The flex assembly **230** in accordance with this embodiment, is manufactured with one lead **264** and one short pigtail lead **266** that includes a solder pad as is shown in FIG. **6**. It may be desired to have the pigtail lead **268** connected to the actuator assembly **110** during the manufacturing process of the actuator assembly **110**, perhaps at a separate vendor, to simplify the final assembly of the disc drive **100**. In this embodiment as in the first embodiment, the flex assembly **230**, with connector **150** attached, is fastened to the base plate **102**. Then the base plate **102** may be placed in a clean environment and the HDA components installed. The lead **268** can then simply be soldered directly onto pad **266**. Finally, the cover **104** is installed as has been previously described.

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As another alternative, the short lead **266** may, in fact, be shortened so as to be outside the cover **104** when the cover **104** is installed. In this alternative, the pigtail **268** would extend beneath the installed cover **104** during the assembly process and the assembled drive removed from the clean environment for soldering of the pigtail lead **268** to the pads on the short lead **266**. Again, in this

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embodiment, the preamplifier **265** may be located on the pigtail lead **268**, or alternatively, if signal conditions permit in the design, preamplifier **265** could be located on the rectangular portion of the flexible circuit **230** adjacent the components **132** and **134**.

5 It will be clear that embodiments of the present invention are well adapted to attain the ends and advantages mentioned as well as those inherent therein. While presently preferred embodiments have been described for purposes of this disclosure, various changes and modifications may be made which are well within the scope of the present invention. For example, the shape and orientation of the
10 flex printed circuit assemblies **130** and **230** and top cover **104** can be changed without departing from the scope of the present invention. The cover **104** may cover portions or all of the flexible circuit assembly **130** in alternative designs.
15 The stiffener **140**, ground plane **142** and power plane **141** may be shaped differently than as described and shown. In addition, the flex circuit assembly of the present invention with a ground and power plane integrated into a stiffener plate may be utilized in other environments than in a disc drive as above described.
Such a flexible circuit assembly as **130** could be utilized in a variety of hand held electronic devices and any electronics assembly that requires the use of a printed circuit board, in place of the printed circuit board. Numerous other changes may
20 be made which will readily suggest themselves to those skilled in the art and which are encompassed in the spirit of the invention disclosed and as defined in the appended claims.